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Interim Report

ORSER-SSEL Technical Report 22-74

INTERPRETATION AND MAPPING OF GYPSY MOTH DEFOLIATION FROM
ERTS(LANDSAT)-1 TEMPORAL COMPOSITES*

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INTERDISCIPLINARY APPLICATION AND INTERPRETATION OF ERTS DATA
WITHIN THE SUSQUEHANNA RIVER BASIN

Resource Inventory, Land Use, and Pollution

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ABSTRACT

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INTERPRETATION AND MAPPING OF GYPSY MOTH DEFOLIATION FROM ERTS(LANDSAT)-1
TEMPORAL COMPOSITES

W. S. Kowalik

Two ERTS(LANDSAT)-1 scenes of July 8, 1973, covering gypsy moth defoliated tracts in eastern Pennsylvania were enhanced by an inexpensive Ozalid color composite technique. Blue Ozalid transparencies of these channel 7 scenes were superimposed over red Ozalid transparencies of October 11, 1972, channel 7 scenes, on which no gypsy moth defoliation is apparent. Superimposing the red and blue transparencies results in color addition to yield a reddish purple where no visible tonal change has occurred, and causes red and blue areas to appear where tonal change within the scenes has occurred.

Defoliation on the color temporal composites appears light blue in a reddish violet background of healthy forest. Photointerpretation of the two temporal composites at a scale of 1:1,000,000 yielded maps of heavy and light-to-moderate defoliation. The interpretation indicates that approximately 164,800 acres were heavily defoliated and another 213,800 acres were moderately defoliated on July 8, 1973, within the area covered by the two images.

ORSER-SSEL Technical Report:

22-74 ABSTRACT, line 2: "...and inexpensive Ozalid color..."
The "O" was left off of "Ozalid."

✓22-74 page 4, paragraph 5: last line should read, "Refoliation prior to July 8..." First word incorrectly shown as "Defoliation."

ORSER-SSEL Technical Report 22-74

INTERPRETATION AND MAPPING OF GYPSY MOTH DEFOLIATION
FROM ERTS(LANDSAT)-1 TEMPORAL COMPOSITES

W. S. Kowalik

Gypsy moth defoliation is an increasingly serious problem in Pennsylvania. Two successive summers of heavy defoliation can kill most hardwoods,¹ and softwoods can be killed by a single defoliation. The Pennsylvania Bureau of Forestry estimated that 857,000 acres of Pennsylvania forest were defoliated by gypsy moths during the summer of 1973, more than twice as much as was defoliated during 1972.² Seventy-nine per cent of that area was heavily defoliated.

Controlling the spread of the gypsy moth is not feasible at present.³ While research into methods of control continues, foresters can only resort to defoliation mapping and localized insecticide sprayings.

Accurate monitoring of defoliation is desirable for several reasons:

1. The location and estimation of tree mortality by mapping of defoliation for successive years is an aid to planning conservation procedures.
2. With successive mapping, localities likely to require spraying as the infestation advances can be determined.
3. Accurate depiction of the extent of the defoliation illustrates the magnitude of the problem and may accelerate basic research in control of the gypsy moth.

Currently, defoliation is mapped by observers from light aircraft. Williams and Turner recently demonstrated the feasibility of mapping gypsy moth defoliation by computer analysis of ERTS(LANDSAT)-1 digital data.⁴ The present study employs photointerpretation of color-enhanced ERTS-1 images to map defoliation.

Defoliation on ERTS Images

Gypsy moth defoliation in eastern Pennsylvania was recorded by ERTS-1 on July 7 and 8, 1973, about a week after peak defoliation. Two July 8 images were used in this study (1350-15183 and 1350-15190; see Figure 1). The coincidence of clear weather and the ERTS passes near the time of peak defoliation was most fortunate.

Mr. C. F. Withington of the U.S. Geological Survey in Reston, Virginia, supplied the Diazo printer for the initial stages of this project. Mr. D. L. Williams of the Department of Forestry at The Pennsylvania State University at the time, and now of NASA, Goddard Space Flight Center, supplied the ground truth data. Support for the work was provided in part by NASA Contract NAS 5-23133.

The defoliated areas are visible on each of the four ERTS multispectral scanner bands. On black and white positive transparencies of bands 4 and 5 (green and red wavelengths) defoliation appears lighter toned within darker healthy forest. It is more apparent on bands 6 and 7 (near infrared wavelengths), as dark tones within lighter tones of healthy forest. Apparently forest floor moisture exposed in defoliated areas absorbed the near infrared wavelengths causing dark tones on these images. Rainfall on the predominantly poorly drained soils in the area during the week prior to July 8 may have contributed significantly to the dark tones on the near infrared images.*

Interpretation of defoliation from either the original black and white positive transparencies or the standard NASA color composites is not straightforward. Defoliated tracts, urban areas, strip mines, and poorly drained areas within the Scranton Wilkes-Barre coal field all have similar tones on the band 6 and 7 images. On individual transparencies of bands 4 and 5, defoliated areas blend with strip mines and urban and agricultural areas. Defoliation on the standard NASA color composites is not easily resolved from bordering agricultural areas or from strip mines and the Scranton - Wilkes-Barre coal field.

Diazo Color Temporal Compositing

In an attempt to achieve an interpretation less speculative than possible with standard images, color temporal composites were made using an available Ozalid printer and developer. Superposition of transparencies of the non-defoliated scenes in one color over transparencies of the defoliated scenes in another color codes the defoliation.

Where no visible tonal changes are apparent, superposition of two images from different dates printed in different transparent color results in compositing of the colors to a continuum of intensities of a third color. Where visible tonal change has occurred within an area, a color approaching one of the two initial colors composited appears. Changes visible on positive transparencies are expressed either as lighter tones, where previous dark areas appeared; or as darker tones where formerly lighter areas appeared. Changes visible on positive Diazo temporal composites will approach the color of the transparency on which the changed areas appear darker, because the Diazo process saturates dark areas in color. (This differs from color composite renditions obtained with typical color additive viewers, in which color saturates the light toned areas.⁶) On band 5, for example, gypsy moth defoliation appeared as lighter tones, whereas prior to the defoliation the healthy forests appeared dark. Therefore, defoliation in the composite will approach the color of the band 5 transparency depicting healthy forests.

*An average of 0.65 inches of rain fell on July 4 and 5, and an average of 3.9 inches fell throughout eastern Pennsylvania on June 28 and 29, after a wet second half of June.

Technique

Color Diazo transparencies were made on a table top Arkwright Diazo Printer and Developer (Models 202 and 101, respectively) using GAF and Escochrome color film. The Diazo machine produces color transparencies at the scale of the original with no detectable loss of resolution.

After experimentation with colors, blue transparencies of the two defoliated July 8 band 7 scenes and red transparencies of two October 11 band 7 scenes were composited for interpretation of defoliation. Color addition of primary red and blue results in violet, providing maximum separation of areas of no change from the reds and blues of changed areas.

Band 7 (near infrared) composites were chosen for interpretation because they provided a clearer rendition of defoliated areas than band 5 (red) composites. Also, air pollution visible on the band 5 image covering the area east and southeast of Allentown and Bethlehem masks forested land and could be mistaken for defoliation in the temporal composites. No composites were made of bands 4 or 6. If rainfall in the area prior to July 8 is causing the dark tones of defoliation visible on bands 6 and 7, then bands 4 or 5 may be useful in future defoliation interpretations.

Interpretation

The temporally composited depiction of the defoliation agrees very well with spot sampled defoliation estimates in Monroe, Pike, and Northampton Counties.* Very blue areas on the band 7 composites represent a range of defoliation from approximately 70 to 100 percent, with an average near 100 percent. These areas are defined as heavily defoliated on Figure 2. A color continuum of light blue with increasing tinges of violet represent areas ranging from 70 to 15 percent defoliation. These areas are identified as the light to moderate defoliation class. Healthy forests and areas defoliated less than 15 percent appear reddish violet on the composites.

All relative tonal changes between the two dates, mainly agricultural field tonal changes and clouds and cloud shadows, are also evident on the temporal composites. Clouds were circled before interpretation, to avoid confusion. Agricultural changes can generally be eliminated on the basis of field patterns.

Interpretation of the color temporal composites is much simpler than interpretation of the original black and white positive transparencies or the standard NASA color composites. Urban areas strip mines, the Scranton - Wilkes-Barre coal field, and most agricultural areas appear as shades of reddish violet on the composites, whereas defoliation appears as shades of blue.

*Ground based estimates of defoliation were obtained from plots on the East Stroudsburg 7.5 minute quadrangle map near East Stroudsburg reservoir, from the Skytop Quadrangle near Camp Girard, and from the Kunkletown and Windgap Quadrangles on Chestnut and Blue Mountains, supplied by the Pennsylvania Bureau of Forestry and the U.S. Forest Service.

North east facing sides of mountains and valleys on the October 11 scenes are somewhat shadowed, whereas on the July 8 scenes almost no shadowing is present. Shadowing tends to mask defoliation in the composites by coloring defoliated areas more violet than nonshadowed areas. The effects of shadowing were considered and taken into account during interpretation.

Mapping

Defoliated areas were traced from the 1:1,000,000 scale composites under 10 power magnification onto a Mylar base map of Pennsylvania at the same scale. The base map is fitted to a Lambert Conformal Conic Projection, providing an essentially orthographic view and permitting transfer of the information by overlay of the satellite images.

The smallest individual defoliated areas defined cover about 50 acres. Boundaries of heavily defoliated areas can be located on the images within approximately 200 meters. The less clear lower boundary of the light-to-moderately defoliated areas is thought to be located within approximately 300 meters. The maximum error in transferring the defoliated areas to the base map is estimated at 500 meters.

The interpretation indicates that on July 8, 1973 approximately 164,800 acres were heavily defoliated (70-100% defoliation) and approximately 213,800 acres (20-70%) were moderately defoliated within the area covered by the two temporal composites. (See Figure 2)

The Pennsylvania Bureau of Forestry estimated a greater acreage of defoliation and a much larger percentage of heavy defoliation within the area considered here. Refoliation prior to July 8 of defoliated areas may explain the discrepancy.

Costs

Mapping gypsy moth defoliation by the method described here is inexpensive. The 9x9 inch ERTS images are available from the Geological Survey EROS data center at Sioux Falls, South Dakota, for \$3.00 per image. Image costs in this study were \$24.00, although only \$12.00 worth of images were required for the final interpretation. In 20 hours experimentation with ERTS bands, film colors, and Diazo machine exposure times, 36 pieces of Diazo film were used. At 26¢ per sheet, film costs amounted to \$9.36. Knowledge gained about film colors, and an exposure time curve which has been empirically derived, should reduce this time and cost in future work by a factor of three. Checking the temporal composites with ground truth information and interpretation required 12 hours. The complete table top Diazo printer and developer retails at \$500. Operation costs of the machine are insignificant.

Conclusions

Photointerpretation of temporally composited color Diazo transparencies of ERTS(LANDSAT) images is a practical method for detecting and locating levels of widespread defoliation. Specifically:

1. ERTS 9x9 inch images are essentially orthographic and are produced at a nearly constant 1:1,000,000 scale. This allows direct superposition of scenes for temporal composites. Only minor correction are required in transferring data to orthographic base maps.
2. ERTS coverage provides a sweeping 180 km (110 mile) wide view, permitting one interpreter to easily delineate defoliation in an area requiring days and weeks of work by aerial surveys or computerized processing. Operator variance present in aerial survey mapping methods is eliminated here. Also, the photointerpreter need not be familiar with local terrain, a requirement for efficient air surveys.
3. Defoliation boundaries can be located on the images within maximum errors on the order of hundreds of meters. This accuracy compares favorably with that achieved in aerial surveys and computer analysis. Enlargement of the composites for interpretation at larger scales will allow greater accuracy in transferring data to base maps than achieved here.
4. The enhancement process described here is much less expensive than aerial surveys or computerized processing. Color additive viewers are not required. Experimentation and production of the final interpretation required about 32 hours work, less than \$10.00 worth of film, and \$24.00 worth of images. Knowledge gained in experimentation will substantially reduce time and costs in future Diazo experiments.
5. The maps produced directly from interpretation are manageable working products. The information is presented in usable form.
6. The 18-day periodic coverage of ERTS is not frequent enough to replace aerial survey mapping because defoliation and refoliation move as waves. Satellite mapping of all areas heavily defoliated as the waves move and peak would probably require cloud free coverage on a weekly basis.

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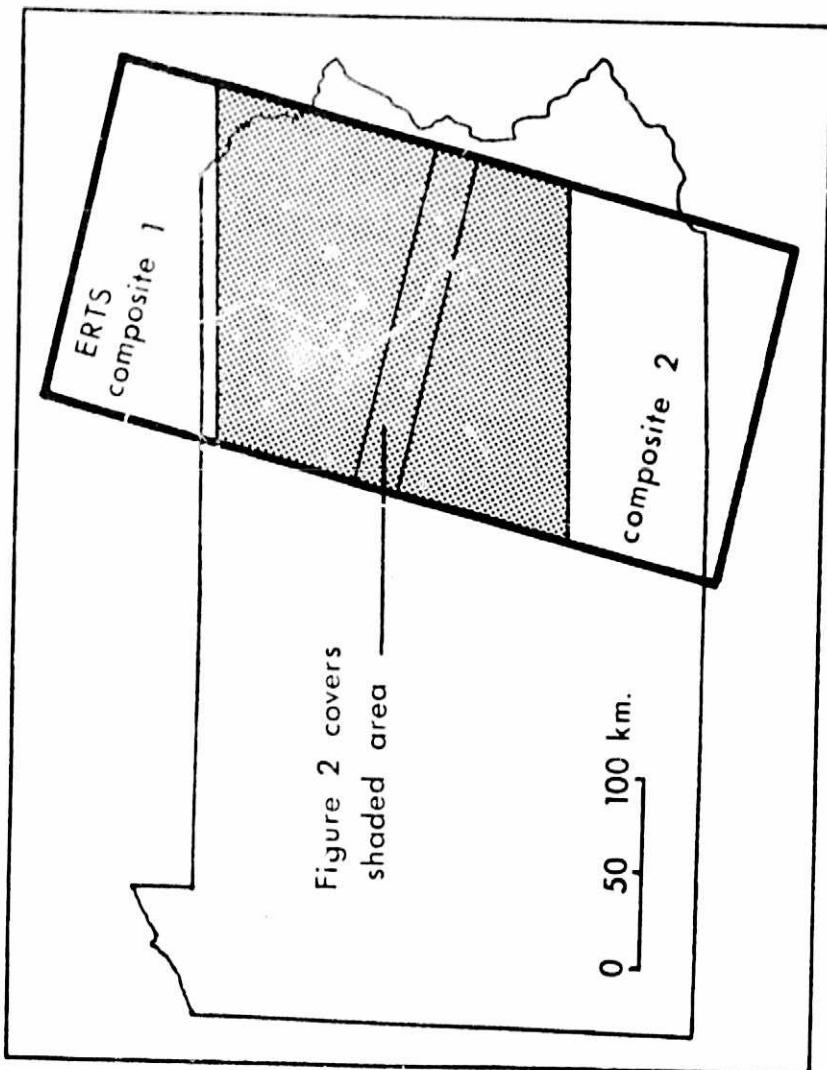


Figure 1: Map of Pennsylvania showing the area covered by the two ERTS composites.

Figure 2: Defoliation in eastern Pennsylvania interpreted from ERTS Ozalid temporal composites. Approximately 371,000 acres were defoliated in this area. Clouds are circled, dotted, and labeled "c".